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Abstract

In a method for estimating channels in TD-CDMA mobile radio systems the receive
values of a number of bursts, which values can be used for the estimation of channels,
are employed to estimate a single channel impulse response in the case where the time
period T_{auf}, in which the successive data bursts are transmitted, is considerably shorter
than the coherence time T_k.

Description

In TDMA-based CDMA mobile-radio systems (TDMA = Time Division Multiple
Access, CDMA = Code Division Multiple Access) it is necessary to perform channel
estimation in order to carry out data estimation. Channel estimation in the TDMA-based
systems is based on a training sequence, commonly called a midamble. The midamble is
5 disposed between two data blocks and the unit consisting of the midamble plus the two
data blocks is called a burst. In this connection, Bernd Steiner in "A contribution to
mobile-radio channel estimation taking particular account of synchronous CDMA

mobile-radio systems with joint detection", Progress Reports VDI, Row 10, No. 337, Düsseldorf: VDI-Verlag 1995, states that the length L_m of the midamble in TD-CDMA mobile-radio systems, which is required by the employed algorithm for channel-estimation purposes, is determined directly by the number of active users K and by the
5 maximum anticipated length W of the channel impulse response through the approximation:

$$L_m \approx W (K + 1).$$

10 Thus the length L_m of the midamble is a factor limiting the number of active users which can exist per burst in the uplink. Where techniques such as "voice activity" or adaptive data rates are to be implemented, it may even be required to support more users than are, as a rule, actually active per burst, in other words to include them in the channel estimation.
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Moreover, if intelligent antennas - i.e. antennas which, for example, work selectively in the direction of the mobile-radio user - are employed in the base station, then user-specific midambles are likewise needed in the downlink, with the result that the midamble length is a limiting factor here as well.
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Also, in TD-CDMA mobile-radio systems having a frequency-reuse factor of $r = 1$, it can be desirable to include inter-cell interference signals from neighbouring cells in the data selection. It is essential here that the estimation include channels in respect of the neighbouring stations or the mobile stations of the neighbouring cells.
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However, this is only possible when sufficiently long midambles are available. This leads to the unsatisfactory situation that, the more channels there are that have to be estimated, the smaller is the remaining portion of the burst which is available for transmitting data. Hence, while on the one hand there is a requirement to estimate a
30 large number of channels, on the other hand only the smallest possible part of the burst is supposed to be given up for the midamble. This is in principle a problem not only with the above-mentioned channel-estimation method of the above-mentioned publication, but with all estimating methods. In order to be able to achieve a sufficiently accurate estimation result, a minimum number of measurement values of the received
35 midamble is required.

Up to now it has not been possible to resolve this conflict in any satisfactory way, but rather, a compromise was found between the midamble length and the portion of the

burst available for transmitting the data. The midamble length is usually set so that there are at least as many channels that can be estimated as there are CDMA codes that can be detected simultaneously in a cell. The number of simultanously detectable CDMA codes is essentially determined by the spreading factor employed and by the intercell

5   interference. Hence a usable compromise between midamble length and the number of estimatable channels is only possible when the spreading factor is not too large, in other words, when relatively few users share the data-transmission capacity of a burst. This presupposes a minimum data rate which is too high for many applications and provides little leeway for the use of the above-mentioned capacity-enhancing measures such as

10 voice activity, adaptive data rates, antenna diversity and the elimination of intercell interference.

It is therefore the aim of the invention to provide a method and device, whereby an increased number of channels can be estimated without the midamble portion of the

15 burst being enlarged.

The aim is achieved by the features of independent claims 1 and 10. Preferred embodiments of the invention are covered by the subclaims.

20 The coherence time T_K is defined as the minimum time interval between two channel impulse responses, within which the channel impulse responses can be considered to be uncorrelated. Also, the coherence time T_K is inversely proportional to user speed.

If now the channel impulse responses of successive bursts are almost identical, i.e. the

25 time period T_{auf}, in which the successive data bursts are transmitted, is considerably shorter than the above-defined coherence time T_K, then the receive values of a number of bursts, which values can be employed for the channel estimation, are used for the estimation of a single channel impulse response. Here users, especially low-speed users, satisfy the condition:

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$T_{auf} \ll T_K$.

Preferably, short midambles may be transmitted inside the burst, the channel estimation then detecting a current channel impulse response from the receive values $e(x)$ of

35 several successive bursts x. The receive values stem from the midamble. In this process it is necessary to take into account the receive values of a sufficient number of bursts during channel estimation, so that the required channel-estimation quality is achieved. This process is possible when the channel impulse responses are as far as possible

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identical inside the time period in which the necessary receive values $\underline{e}(x)$, x=1...X are received, in other words when the condition $T_{auf} \ll T_K$ is satisfied. Moreover, the lower the speed of a mobile station, the shorter can be the midamble, since then the coherence time T_K is all the greater and a correspondingly higher data rate can be attained.

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By using the idea of transmitting the midamble piece by piece, it is possible to gain an increase in the number of users. Certainly, if the length of the midamble within the bursts is allowed to be the same and if these are interpreted as being sections of a longer midamble, it is possible to accommodate substantially more users. Hence the problem of

10 the strictly limited number of users in TD-CDMA mobile-radio systems, this limited number being normally due to the channel estimation, can be considered to be solved.

Moreover, it is not absolutely necessary to use midambles on the assumption that the estimation $T_{auf} \ll T_K$ is valid within a burst, but it would be possible, generally speaking,

15 to use preambles. Advantageously, preambles could be chosen to be shorter than midambles on account of their property that they are not disturbed by the interference of preceding symbols, so that the data rate, for example, is increased as a result. Where preambles and midambles are of equal length, the use of preambles can lead to a higher user count.

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Preferred embodiments of the invention are now described with the aid of the drawings, of which:

Fig. 1 shows a midamble divided up into several shorter midambles, and
25 Fig. 2 shows the use of periodic midamble codes.

Fig. 1 shows a midamble $\underline{m}$ divided up into several midambles, $\underline{m}(x)$, where $1 \leq x \leq X$. By transmitting the midamble $\underline{m}$ in segments in successive bursts, the midamble of a burst is shortened, the result being an increase in the number of channels that can be
30 estimated on account of the short midambles.

In this particular example, the midamble $\underline{m}$ consists of X=5 blocks of length W. The receive signal originating only from the midamble $\underline{m}$, which has not yet been divided up, is given for any user K by:

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$$\underline{e}_{m,i}^{(k)} = \sum_{n=0}^{n=W-1} \underline{m}_{i-w-n}^{(k)} \cdot \underline{h}_n^{(k)} \quad , \quad i = 1,...,KW \qquad (1)$$

When the signals of the K subscribers are superposed, the entire receive signal originating from the user midambles becomes:

$$\underline{e}_{m,i} = \sum_{k=0}^{k=K} \underline{e}_{m,i}^{(k)} \quad , \quad i = 1,...,KW \qquad (2)$$

5 Moreover, the receive sequence $\underline{e}_m$ is shorter than the midamble by W elements, since receive values with interference from the data blocks cannot be used for channel estimation.

So that the same algorithm as before can be used for channel-estimation purposes after
10 the midamble has been divided up among several bursts (the algorithm is based on the receive sequence $\underline{e}_m$ of length KW), the signal $\underline{e}_m$ must also be produced by the transmission of the midamble in sections. In the example shown in Fig. 1, the signal $\underline{e}_m$ is composed of four subsignals $\underline{e}_m = [\underline{e}_m(1)...\underline{e}_m(4)]$, when the midamble $\underline{m}$ is distributed among X=4 bursts. In this process the receive values of $\underline{e}_m(1)$ result from the
15 transmission sequence of the midamble part $\underline{m}(1)$ and, since the channel impulse response is of length W, from the W-1 previous sample values from the block $\underline{m}(0)$. The receive values of $\underline{e}_m(2)$ result from the transmission sequence $\underline{m}(2)$ and, since the channel impulse response is of length W, from the W-1 previous sample values from the block $\underline{m}(1)$. A similar process applies to the receive values $\underline{e}_m(3)$ and $\underline{e}_m(4)$.
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After the transmission of the four bursts, as illustrated in Fig. 1, the identical signal $\underline{e}_m = [\underline{e}_m(1)...\underline{e}_m(4)]$ can be assembled from the four receive sequences when the channel impulse response is constant. Channel estimation can be economically performed using a process outlined in the above-mentioned article.
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The channel impulse response can be estimated in the steady state after the receipt of each burst and hence of each segment $\underline{e}_m(x)$, when, for example, an older $\underline{e}_n(1)$ is replaced by a similar segment which has been just received. Hence the result of the channel estimation is made to adaptively track the slowly changing channel.
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Figure 2 shows how blocks of the midamble arise out of a periodic midamble basic code described in the above-mentioned publication. When the supported number of users K is a multiple of the number of bursts X among which the midamble is divided up, the dividing up of the midamble is expressed in the channel estimator as a cyclical exchange
35 of the midambles employed by the users. With each burst, then, exactly the same channel estimator can be used, which employs in each case the midamble receive

signals of the last X bursts. The estimation value $\underline{h}$ of the channel impulse responses is expressed with the constant, right-circulating matrix $\underline{G}^{-1}$, which is dependent only on the midamble code used, as:

$$\underline{h} = \underline{G}^{-1} \underline{e}_m \qquad (3)$$

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Since only a part of the receive sequence $\underline{e}_m$ is newly obtained per burst, it is not absolutely essential to carry out a complete channel estimation with each burst. As a linear estimation algorithm is involved, it is possible instead to determine directly from the difference between the old and new receive sequences $\underline{e}_m$ the difference between the old and new estimations of the channel impulse response and to update the estimation result $\underline{h}$.

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In the Fig. 2 example, $X = K = 4$. The periodic basic code PGC is subdivided into four components, each beginning with $\underline{m}_1$, $\underline{m}_{w+1}$, $\underline{m}_{2w+1}$ and $\underline{m}_{3w+1}$. Here the periodic basic code PGC ends with the symbol $\underline{m}_{KW}$. Between the users T1, T2, T3 and T4 the basic code PGC just mentioned is in each case always offset periodically by one block, wherein in the midamble M_1 the user T1 transmits the components $\underline{m}_1$ and $\underline{m}_{w+1}$, while the subscriber T2 transmits the components $\underline{m}_{w+1}$ and $\underline{m}_{2w+1}$, user T3 transmits the components $\underline{m}_{2w+1}$ and $\underline{m}_{3w+1}$ and user T4 transmits the components $\underline{m}_{2w+1}$ and $\underline{m}_1$ in this order. Accordingly, the eight components of the periodic basic code PGC are transmitted in the midambles M2 to M4. These components are each arranged above them in Fig. 2. In this process the midamble M1 is transmitted in the first burst B1, while the midambles M2 to M4 are transmitted in the corresponding succeeding second to fourth bursts. The partial figure at the bottom right of Fig. 2 shows the components of the first midamble M1, which is transmitted in the first burst B1.

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Claims

1. Method for estimating channels in a TD-CDMA mobile-radio systems, characterized in that, to estimate an individual channel impulse response $\underline{h}$, the receive values $\underline{e}_m(x)$, $x = 1,...,X$ of several bursts are employed, which values can be used for the channel estimation, when the time period T_{auf}, in which the successive data bursts are transmitted, is considerably shorter than the coherence time T_K.

2. Method according to Claim 1, characterized in that the condition $T_{auf} \ll T_K$ is true for low-speed users.

3. Method according to one of the preceding claims, characterized in that the midamble $\underline{m}$ required for channel estimation is divided up among several part-midambles $\underline{m}(x)$, where $x = 1,...,X$, wherein each part-midamble $\underline{m}(x)$ is transmitted in a burst of a series of X bursts, with the result that the entire midamble $\underline{m}$ is composed of the part-midambles $\underline{m}(x)$ of the successive bursts.

4. Method according to one of the preceding claims, characterized in that, during channel estimation, the partial receive values $\underline{e}_m(x)$, $x = 1,...,X$ of the receive signal $\underline{e}_m$ of a sufficient number of bursts are taken into account so that the required channel-estimation quality is achieved.

5. Method according to one of the preceding claims, characterized in that the estimation of the channel impulse response $\underline{h}$ in the steady state is carried out after the beginning of each burst and of each segment $\underline{e}_m(x)$.

6. Method according to one of the preceding claims, characterized in that preambles are used instead of midambles.

7. Method according to one of the preceding claims, characterized in that the channel is adaptively tracked by replacing an older segment $\underline{e}_m(x)$ of the burst receive-signal $\underline{e}_m$ by the segment just received.

8. Method according to one of the preceding claims, characterized in that a periodic basic code is employed for generating the user midambles.

9. Method according to Claim 8, characterized in that the dividing-up of the midamble is expressed in the channel estimator as a cyclical exchange of the midambles employed by the users when the supported number of users K is a multiple of the portions X of the bursts, among which the midambles are divided up.

10. A TD-CDMA mobile-radio system employing the method according to one of the preceding claims.

Herewith 2 pages of drawings